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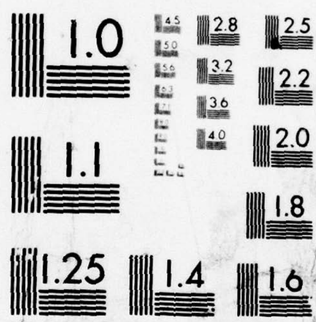

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DTIC ACCESSION NUMBER

LEVEL II

INVENTORY

Operation Snapper. Test conducted as part of Exercise Desert Rock IV. May-June 1952
The Susceptibility to Damage and the Protection Afforded By Quartermaster Items. I. Clothing II. Cl.--- III. P.-- IV P.---

DOCUMENT IDENTIFICATION

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OPERATION SNAPPER. TEST CONDUCTED AS PART OF
EXERCISE DESERT ROCK IV.
MAY-JUNE 1952

#9

THE SUSCEPTIBILITY TO DAMAGE AND THE PROTECTION AFFORDED BY QUARTERMASTER ITEMS

I. Clothing
II. Clothing Fabrics
III. Protective Cream
IV. Packaging

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DOC ✓
SLN
DDC

By

JOHN M. DAVIES
Philadelphia QM
Research and Development
Laboratories

26 May 1953

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ACKNOWLEDGMENTS

These tests were performed as part of Exercise Desert Rock IV, carried out by Sixth Army under direction of the Chief of Army Field Forces. We wish to thank the Chief of Army Field Forces for allowing Quartermaster Research & Development to take part in the test and the Test Director, Gen. H. P. Storke, and his staff, for assistance in conducting the tests. Major D. E. Kieffer was particularly helpful. Lt. Edwards of the Signal Corps Photo Detachment took the photographs at the site.

Lt. Col. D. C. Hughes of the Quartermaster Board, Ft. Lee, Va., was the Project Officer at the Test Site assisted by Major Howard James, Lieut. Frank Simpson and Pfc. Nannig. Lieut. Simpson was especially helpful in locating shipments and setting up samples for exposure in Shot 6 before the others arrived.

A considerable amount of help was given by members of the Philadelphia QM Research and Development Laboratories. The dummies, clothing and many of the fabric samples were obtained by Mr. Elliott A. Snell of the Engineering Test Division. Other materials were furnished by Mr. Frank J. Rizzo of the Dyeing and Finishing Branch of the Textile Division and by Mr. F. Tartaglia of the Clothing Division. The temperature indicators were furnished by Dr. J. D. Loconti of the Pioneering Research Division. The preparation of samples and indicators was largely handled by Mr. Emery Utterback of the Pioneering Research Division, assisted by Miss Norma Weber of the Engineering Test Division. Reflectance and transmittance data were obtained by Mr. Samuel P. Cohen and his staff in the Pioneering Research Division. A number of photographs were taken by Mr. John Salmon of the Photography Division of the Philadelphia Quartermaster Depot.

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SUMMARY

Clothing on dummies and fabrics on panels, protective cream on panels, and boxes were exposed to the thermal radiation of Shots 6 and 8 of Operation Snapper as part of Exercise Desert Rock IV. Exposures were made at 4, 5, 10 and 13 langleys (1 langley = 1 calorie per sq. cm.) Protection was measured with temperature indicators.

The clothing included standard items making up various ensembles, such as hot wet, hot dry, temperate, cold wet and cold dry. The fabrics on panels included essentially the same fabric combinations and various other fabrics to study reflectance, insulation, a variety of materials, including heat treated orlon, wool and synthetic fiber blends, and arrangements, including spacing and order of layers.

Except for a few items there was little damage at 5 langleys. The exceptions were the cotton nylon parka which shredded, the fur ruff which melted and the wool fabrics which scorched slightly. At 10 to 13 langleys all single layers of fabrics and all outer layers of fabric combinations were badly damaged. The damage to fabrics as clothing and on panels was about the same and any differences can be accounted for on the basis of angle of incidence.

Generally the damage was less for fabrics in contact with a solid backing. High reflectance reduced the damage. Wool was more sensitive than cotton at low intensities but less sensitive at high intensities. Blends of synthetics with wool up to 15 percent were about as resistant as wool but a 30 percent blend of dacron was damaged considerably. The heat treated orlon was very resistant. An aluminized cotton was very good.

There is still some uncertainty in interpreting protection from temperature indications and the conclusions are subject to revision. It seems, however, that the lighter ensembles, such as hot wet and hot dry, did not provide adequate protection in single layers for intensities of 10 to 13 langleys. Under pockets, seams, plaits and folds, the protection was adequate at this intensity. The temperate and heavier ensembles provided adequate protection at this level. Temperatures behind fabrics on panels were higher than behind clothing, largely on account of effects of angle of incidence and drape and spacing. White fabrics did not provide as much protection as might be expected from the resistance they offer to damage and generally not as much as dyed fabrics. Likewise the black heat treated orlon did not provide outstanding protection. The aluminized cotton was outstanding and for a corresponding weight provided more protection than any other fabric. Behind the black orlon most of this advantage was lost. The temperatures back of the camouflage shades were just slightly higher than for higher reflecting shades. There was no difference between the undyed and dyed frieze back of 9 oz. sateen, OG-107. Reversing the order of layers gave

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slightly lower temperatures as might be expected from the high reflectance of underwear fabric. Moving the 1/4 in. space from between backing and underwear to between underwear and undershirt had little effect. Varying the spacing had appreciable effect and 1/2 inch is much better than 1/16 in. The protection improves rapidly with increase in weight. All of these results are in fair agreement with results of previous tests or with principles established from them and from theoretical considerations.

QM protective cream afforded considerable protection and seemed to be adequate up to 13 langleys if used in layers 1/16 in. thick and possibly adequate if somewhat thinner.

The packaging test was not very successful. Very likely the inconsistent results were due to dust obscuration at the higher intensities. The temperatures of 56 to 74° C may be correct for 10 langleys but until corroborated they can be taken only as a lower limit.

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CHAPTER 1

OBJECTIVES AND GENERAL PLAN

1.1 OBJECTIVES

Materials were exposed to the thermal radiation of two shots of Operation Snapper, in connection with Exercise Desert Rock IV. There were four phases of this test; studies of: 1. Clothing; 2. Clothing fabrics; 3. Protective cream; and 4. Packaging; with corresponding objectives;

(1) To determine the damage to and the protection afforded by standard clothing ensembles.

(2) To compare clothing fabrics exposed on flat panels, as to protection and damage, and to determine the importance of

a. Reflectance, especially of camouflage shades.
b. Spacing.
c. Weight and number of layers.
d. Arrangement of layers.
e. Blending of wool and synthetic fibers.

(3) To determine the protection afforded by QM cream, protective flash burn.

(4) To determine the temperatures reached inside wood boxes.

1.2 HISTORY AND GENERAL PLAN

Fabric samples have been exposed in previous tests but clothing ensembles have not been studied. There have been no QM tests of protective cream or packaging. On the latter three items then the tests were of a preliminary nature, designed to learn how to test the items as well as to get specific data. The results of Operation Buster[1] showed that spacing affects the protection afforded by fabrics and accordingly the drape of clothing is important. Also, since the protection increases rapidly as the number of layers is increased, as shown at Operation Ranger[2] the effects of folds, pockets, seams and similar factors is important. It is difficult to simulate these effects on panels and so it seemed desirable to expose clothing on dummies. Since it was not possible to obtain full body dummies, torso dummies were used, exposing only upper body clothing. This was not entirely satisfactory but as Operation Upshot was at that time scheduled for the fall

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of 1952 and additional clothing exposures were planned for that test and for Knothole, it seemed that torso dummies would give the information needed to plan for future tests.

Some other principles of protection were established in previous tests and it was desired to verify some of them and extend others. For example, white fabrics were resistant to damage but did not afford correspondingly better protection and since this did not seem to be generally accepted, one white fabric was included here. Camouflage shades absorbed a little more energy than standard military shades with corresponding poorer protection but the differences were small. Since the previous tests, two such shades were standardized and both were included, OG-107 on cotton and OG-108 on wool. Simulated skin temperatures were generally lower when the fabric was spaced from the backing and a few tests were included to determine whether the spacing distance is important. In spite of the extreme sensitivity of nylon, blends of nylon and wool were about as good as wool and accordingly, blends of wool and other synthetics were exposed in this test. All of the fabrics were exposed on flat panels

The cold-bar suit utilizing the vapor barrier protection principle is undergoing extensive tests and a flat sample of the material was included here.

Standard QM items afford considerable protection but with the possibility of surprise and lack of time for evasive action, there is considerable concern about extensive burns on unprotected skin. Skin creams might protect parts of the body not usually covered, such as hands, face and neck and samples were included to determine the protection afforded by QM flash burn cream.

Future tests will include studies of damage to stores; in particular a packaging study is planned for Operation Knothole. To obtain data to permit better planning for that test, a preliminary study was made here which included determination of temperatures inside wood boxes at fairly high thermal intensities.

In all cases the basis of temperature measurement and protective value of various items was the performance of temperature indicators of the type used in both Ranger and Buster. Those used in this test were similar to those used at Buster with some improvement in a few individual cases and they were used in about the same manner as at Buster.

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CHAPTER 2

OPERATION AND GENERAL PROCEDURE

2.1 GENERAL

Samples were exposed at Shot 6 and Shot 8 of Operation Snapper on 25 May and 5 June 1952. Both of these were tower shots, about 300 feet high and both were predawn, about 0400 hours. The test areas are shown on the map on page 6 of the Test Director's Report[3]. Clothing on dummies and fabrics and protective cream on flat panels were exposed to energies of 4 to 13 langleys (1 langley = 1 calorie per sq. cm.). This was intended to be 6 to 15 langleys but the yields were lower than expected. Boxes were exposed on Shot 8 only at levels up to 42 langleys. Temperature indicators, unprotected and covered with thin transparent film were exposed at about 0.7 langleys.

2.2 THERMAL INTENSITIES

The actual exposures are listed in Table 2.1. No measurements of thermal radiation were made at these locations. The intensities were calculated from thermal yields supplied by the Armed Forces Special Weapons Project[4], based on measurements made by the Naval Research Laboratory at the Control Point and measured atmospheric transmissibilities of 95 percent for Shot 6 and 94 percent for Shot 8. The distances for clothing, panels and unprotected indicators were approximately 1, 1-1/2 and 4 miles and when these approximate figures are used they will refer to the distances listed in Table 2.1.

The intensities for tower shots are always uncertain because of the possible attenuation of radiation by dust. Dust may be raised by the shock wave, travelling thru air or thru air and ground, or by the popcorn like bursting of soil particles exposed to intense thermal radiation of more than about 5 langleys[5]. For Shot 6 the samples at 1 and 1-1/2 miles were on high ground above ground zero, roughly on the opposite side of the tower from the troop location. The sample at 4 miles was near the troop location. It is not likely that dust affected these exposures. For Shot 8 all the samples were on fairly level ground. There were no internal inconsistencies in the results, however, for the samples of Shot 6 and those of Shot 8 at 1, 1-1/2 and 4 miles. There were inconsistencies for the closer samples of Shot 8 which possibly can be explained as due to dust obscuration.

2.3 WEATHER

Temperature and humidity data were also supplied by the Armed Forces

Special Weapons Project[4] and are given in Table 2.2. The values given are for measurements at the Control Point with the exception that the value at shot time was calculated for ground zero from the Control Point data.

2.4 REFLECTANCE AND TRANSMITTANCE OF MATERIALS

The reflectances of many of the fabrics of the ensembles, the fabrics for the panel exposures and the protective cream were measured with a General Electric Spectrophotometer. The nature of the variation with wave length is shown in Figs. 2.1 and 2.2; the curves for clothing items not shown are similar. The average reflectances for the outer layers of the clothing ensembles are given in Table 3.2 and for the panel fabrics in Table 4.2. The averages are for the ranges 0.4 to 0.7μ and 0.7 to 1.0μ, designated here as visible and infra red.

For some fabrics, such as the 9 oz. sateen dyed OD-7 or OG-107, the transmittance in the visible region is small, as measured for Operation Buster[1], generally less than 1/2 percent. For other fabrics, such as undyed or light colored or loosely woven fabrics it may be much higher. Measurements were made on a number of the fabrics using the General Electric Spectrophotometer in about the same manner as for Operation Buster. Much of the radiation is scattered and the result depends on the solid angle seen by the collector. The geometry was the same for all fabrics but there is some uncertainty about the exact value of the solid angle. The results are given in Fig. 2.3 and the average values in Tables 3.1 and 4.1.

2.5 TEMPERATURE INDICATORS

The indicators were of the same type used in Operation Buster. They were cut into pieces 1/4 in. by 1 in. and mounted in groups of 12, held face down in contact with the backing by adhesive tape along the ends. On the flat panels a fine line of latex cement along the center line was used in an attempt to improve the contact.

The indicators in the two groups were: M-5 paint, 48, 56, 62, 68, 74, 79, 84, 92, 100, 106, 118°C; 125, 133, 146, 157, 161, 175, 180, 205, 223, 240 and 257°C.

As yet there is not enough information to permit definite interpretation of temperatures in terms of skin injury. Results at Operation Ranger showed that the period of time during which the backing was at high temperature was very short and likely the maximum permissible temperature is considerably above the accepted value of 70°C for 1 second. A few preliminary results at the University of Rochester[6] show that for

140°C
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a 1/2 second exposure behind 2 layers of fabric, an indication of 14°C, on indicators arranged with essentially air backing, is about equivalent to a 2+ burn. This result needs verification but the value can be used tentatively until more complete results are available.

As before, the indicators show a range of temperatures rather than a single definite value. Each result is given as two values; the lower is the highest temperature for complete change and the temperature was certainly that high; the higher is the highest temperature for any change in the indicator and the temperature was probably nearly that high.

TABLE 2.1

Calculated Radiant Exposures

Distance from Ground Zero, ft.	Radiant Exposure langleys	Samples Exposed: Clothing on Dummies	Fabrics on Panels	Protective Cream	Boxes	Unprotected Indicators
				Shot 6		
5400	10.3	X	X	X		X
8400	4.2	X	X	X		X
21000	0.6					X
				Shot 8		
2910	41.6				X	
4110	19.3				X	
5210	12.7	X	X	X		X
5810	10.2				X	
8250	4.9	X	X	X		X
20000	0.7					X

TABLE 2.2

Temperature and Relative Humidity. All data at the Control Point except for H Hour; H hour result calculated for shot area

Approx. Time Hours	Shot 6 Temperature	Shot 6 Relative Humidity	Shot 8 Temperature	Shot 8 Relative Humidity
H-3-1/2	61°F	35%	67°F	34%
H-2-1/2	58	38	65	36
H-1-1/2	59	42	63	39
H- 1/2	57	42	62	39
H	57	41	64	45
H+ 1/2	57	46	60	44

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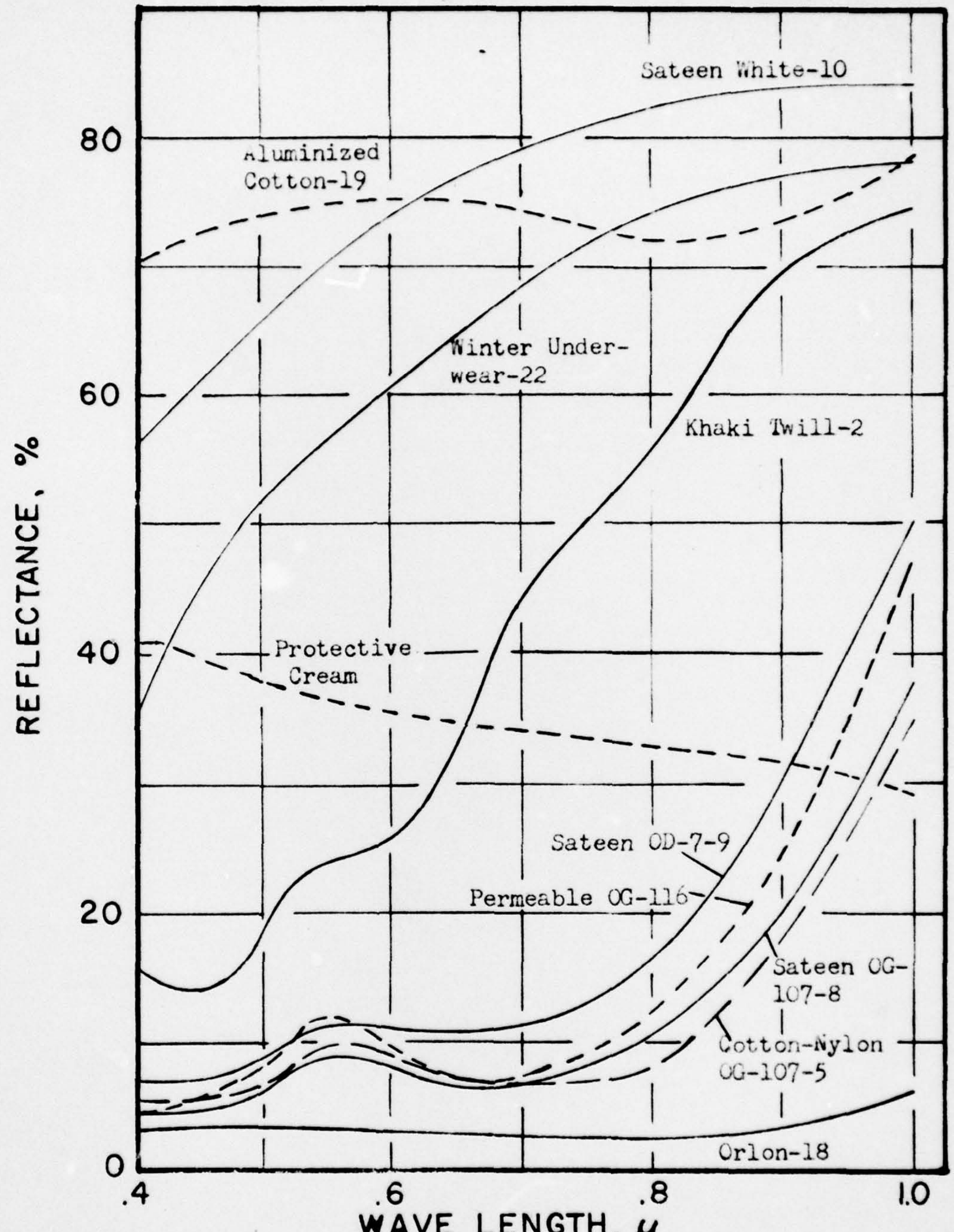

Fig. 2.1 Reflectance of Cotton and Orlon Fabrics and Protective Cream. Numbers refer to Table 4.1

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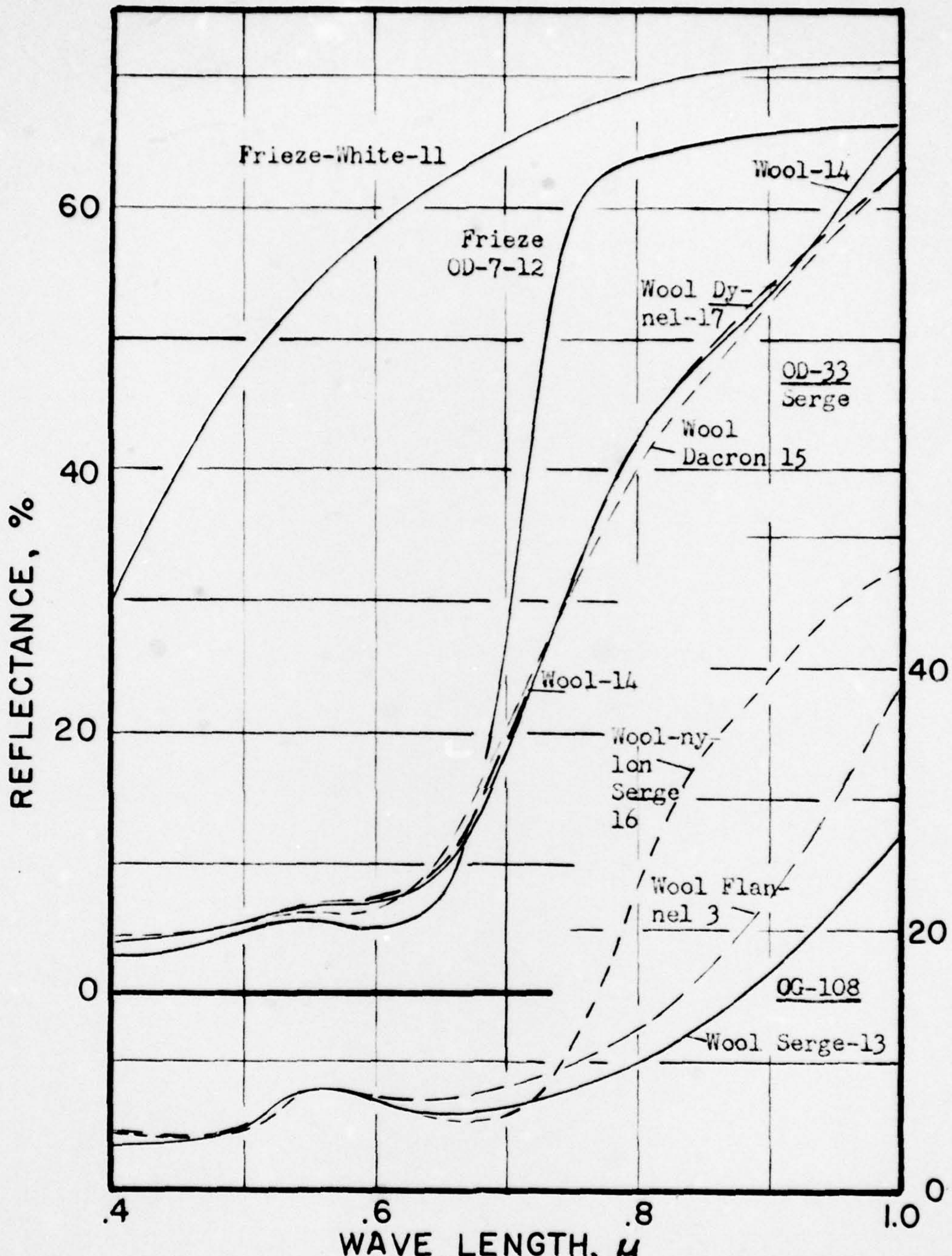

Fig. 2.2 Reflectance of Wool Fabrics.
Numbers refer to Table 4.1

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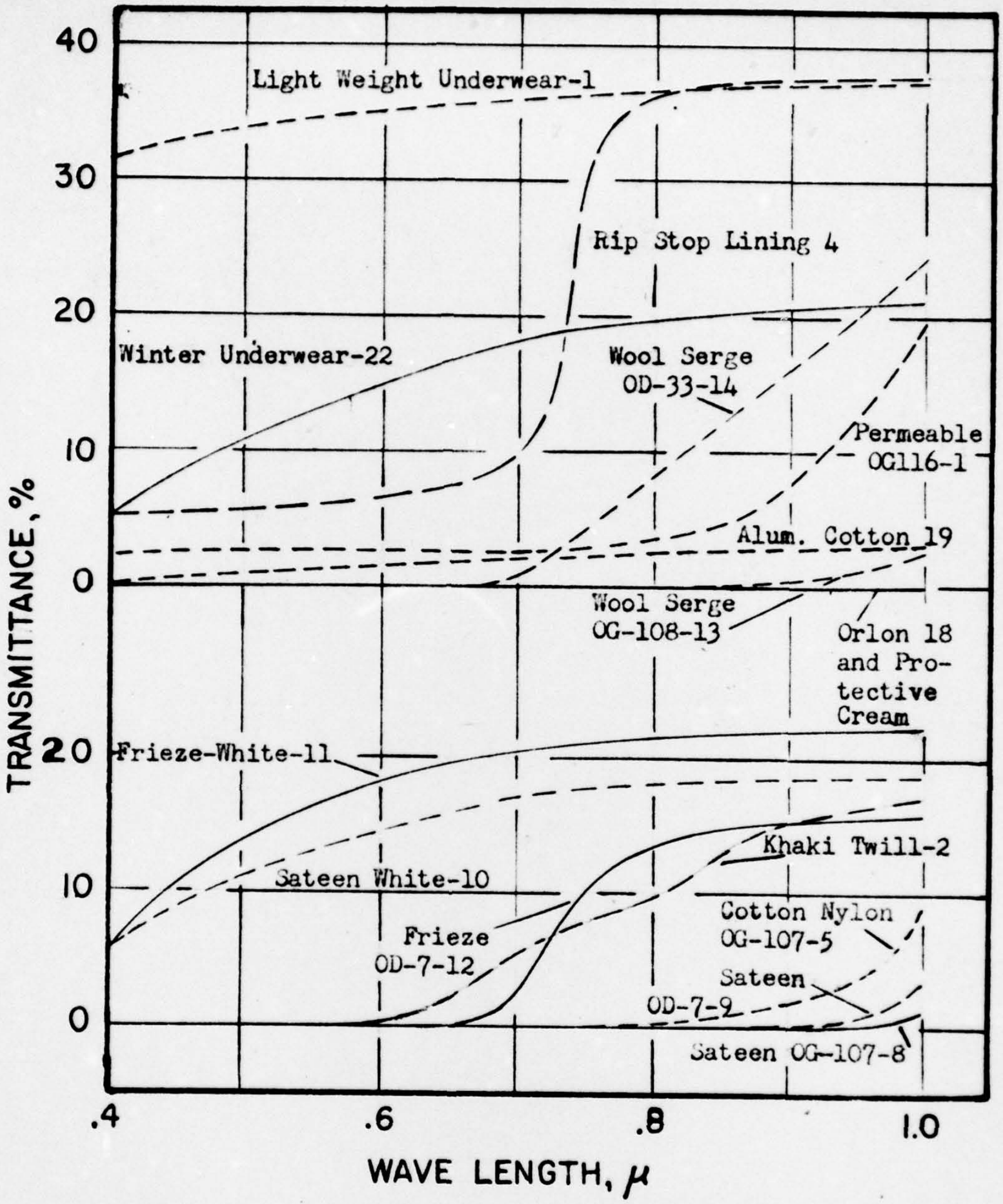

Fig. 2.3 Transmittance of Materials.
Numbers refer to Table 4.1

CHAPTER 3

CLOTHING ON DUMMIES

3.1 PROCEDURE AND MATERIALS

The plan was to expose 5 ensembles; hot dry, hot wet, temperate, cold wet and cold dry. At the time of the test, however, the hot dry and hot wet ensembles were not yet standardized. Accordingly substitutes were used; the 8.2 oz. uniform twill shirt khaki I and lightweight under shirt, white, for the hot dry ensemble and the 5.5 oz. permeable cotton OG-116 or 6 oz. wind resistant sateen shirt OD-7 and the light weight undershirt, white, for the hot wet ensemble. In referring to these ensembles they will be designated hot wet and hot dry. The temperate combination included part of the cold wet ensemble; for Shot 6, undershirt, shirt and jacket without liner and for Shot 8, undershirt and shirt. The clothing exposed on each shot is listed in Table 3.1. The average reflectance of the outer layers and the average transmittance of some layers are given in Table 3.2. The ensembles were exposed on dummies shown in Fig. 3.1. To measure the protection, the temperature indicators described in Section 2.5 were placed as shown. In addition for the cold dry ensemble the dummies were fitted with heads to accommodate the hoods and sets of indicators were placed on each cheek to indicate high temperatures that might be reached if the ruff burned.

3.2 DAMAGE TO CLOTHING

In general there was little damage to clothing exposed to 4 to 5 langleys at about 1-1/2 miles, but severe damage to outer layers exposed to 10 to 13 langleys at about 1 mile. In some cases there was considerable damage to underlying layers, such as underwear under the lightweight outer garments and lining of jackets. The clothing varied in weight and number of layers, type of material and shade and the angle of incidence varied over the surface of each garment. Consideration of these variables accounts for much of the difference in damage.

As is usually the case in field tests of this kind, it is difficult to assess separately the damage from thermal and from blast effects. In some cases possibly the radiation weakened the fabric and the wind blew it away. At any rate parts of garments were gone and it is not possible to say whether they afforded some protection during the flash or were burned away very quickly.

Photographs taken at the site are shown in Figs. 3.2 to 3.21. Since there was little visible damage at less than 6 langleys except

for small effects of the blast the photographs of samples at 1-1/2 miles generally will serve to indicate the condition of all the clothing before exposure. The scorching of the dummies and under layers is shown in Figures 3.22 and 3.23.

3.2.1 Hot Wet Ensemble
Shot 6
4 Langleys at 1-1/2 Miles
No visible damage to jacket or undershirt.

10 Langleys at 1 Mile
Jacket. Badly burned. Single layer areas burned away, also outer layer of shoulder, collar and pockets and center plait. Some remaining fragments charred black. Underlying layers of jacket scorched.

Undershirt. Under a single layer of jacket undershirt was scorched badly, dark brown. Some scorching around edges of collar and pockets but little scorching at center of pocket area. Undershirt shows effect of drape; it fitted snugly on the dummy and the jacket hung away from the undershirt near the waist with less scorching of the underwear. This is shown in the photograph of Figure 3.23.

Shot 8
5 Langleys at 1-1/2 Miles
No visible damage to jacket or undershirt.

13 Langleys at 1 Mile
Jacket. Similar to corresponding position, Shot 6, but burned more. Practically all single layer fabric gone and most of outer layer of multilayer sections. Buttons scorched.

Undershirt. Scorched and burned under single layers of jacket. Badly scorched on shoulders. Shows effect of drape as for Shot 6.

3.2.2 Hot Dry
Shot 6
4 Langleys at 1-1/2 Miles
No damage to shirt or undershirt.

16 Langleys at 1 mile
Slight scorching on front of shirt; fabric intact. No damage to undershirt.

3.2.4 Cold Wet
Shot 6
4 langleys at 1-1/2 miles
No visible damage to any garment.

10 langleys at 1 mile
Similar to temperate but slightly less damage. Some of front charred and burned away. Left side worse than right. Under layers scorched where top layer was burned away or charred badly and still in place.

Under Layers. Pile liner scorched slightly, mainly on left side.

Shot 8
5 langleys at 1-1/2 miles
No visible damage to any garment.

13 langleys at 1 mile
Jacket. Damaged more than similar ensemble in Shot 6 or Temperate in Shot 6. Enough of top layer burned to expose under layers. Steen lining and undyed buckram and drill interliners were scorched. Under side of left pocket was scorched considerably indicating outer layers were burned away before flash was over.

Under Layers. The pile liner was scorched over most of the front but especially in the upper chest area. The collar of the wool shirt was scorched where exposed but not damaged otherwise. No scorching of undershirt.

3.2.5 Cold Dry
Shot 6
4 langleys at 1-1/2 miles
No visible damage to any garment except fur ruff on hood. Outer ends of wolverine fur burned or melted to a depth of about 3/4 inch. Synthetic ruff not damaged.

10 langleys at 1 mile
Parka. Most of front surface gone. In places the nylon filling yarn melted leaving the cotton warp unsupported. Over most of the area all the fabric was gone. The natural fur ruff was burned and melted, worse than for exposure at 6 cal. per sq. cm. The nylon ruff was damaged more, almost all melted.

Under Layers. The pile liner for the parka was badly

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scorched especially in the upper chest area. Other layers not affected.

Shot 8

5 langleys at 1-1/2 miles

Parka. Over much of the front area the nylon filling was melted leaving the fabric shredded. Generally there were small areas and the garment as a whole remained in place.

Under Layers. There was no visible damage on the pile liner or other layers.

13 langleys at 1 mile

Parka. The front surface was burned or blown away with evidence at the edges of the melting of the nylon filling.

Under Layers. The pile liner of the parka was badly scorched, dark brown in places. There was no visible damage to other garments.

3.2.6 Summary

In general the results are about as expected from previous tests. The intensities of radiation were lower than expected and probably more information would have been obtained by exposing the heavier clothing at higher intensities. With the exception of the shredding of the nylon filled parka, the melting of the fur ruff and the scorching of the wool shirt, there was no visible damage up to 5 langleys. At 10 to 13 langleys the lighter clothing and the outer layers of the heavier clothing were very badly damaged and would afford little or no protection after the flash.

In all cases the khaki shirt was damaged less than the OD-7 or OG-107 garments. In some cases it was a little heavier but likely most of the difference was due to its higher reflectance.

The effect of angle of incidence is evident in the nonuniform scorching and charring fabrics of both for fairly smooth curved surfaces and for fairly flat surfaces which were not smooth.

The effect of spacing between layers is evident in the effect of drape in keeping the outer layers from making contact with the underwear.

The effect of added layers is evident from the protection afforded by seams, folds, plaits, collars and pockets. For an erect

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soldier, the upper chest, above the pockets, seems to be a place of maximum damage, partly because the beam is incident at nearly zero angle and also there are fewer layers in that area.

The natural fur ruff was damaged slightly at 4 langleys but withstood 10 langleys better than the nylon ruff which was completely melted. Neither seems to be satisfactory in this respect.

The nylon filled cotton outer layer of the parka performed very poorly. This might be expected from previous tests on all nylon fabrics. Likewise, previous experience indicates that blends of synthetics with wool perform nearly as well as wool alone and possibly blends of nylon with cotton will also show resistance to damage. If the desired properties cannot be achieved at low weight in this way then some more resistant material should be substituted for the nylon.

The wool shirt was badly damaged but the slight scorching of the undershirt indicates that ~~it~~ the shirt remained in place and afforded considerable protection.

Although as indicated by the lack of scorching of underlayers and the temperature indicator results given later, the heavier clothing provided adequate protection, it should be realized that in some cases the outer garment was damaged so badly that it would not afford adequate protection after the flash. For example, the parka exposed to 10 to 13 langleys would not protect a soldier against wind or rain and even if he survived the atomic blast probably he could not survive against the elements afterward.

3.3 PROTECTIVE VALUE OF CLOTHING

It is obvious from the effects of angle of incidence, drape and variation in thickness and number of layers that a large number of indicators would be needed to determine the maximum temperature attained and the range to be expected. Of the seven sets of indicators used, one was essentially a control, two were under the arms where the angle of incidence was high, one was on the chest where the angle of incidence was low but generally more than the minimum number of layers was over the indicator, one was at the waist and again under a number of layers, two were on the shoulders where there were usually added layers and also where the angle of incidence was high. The scorching of under garments, for example the undershirt for the hot wet ensemble at 10 langleys in Shot 6 and 13 langleys in Shot 8, and the pile jacket liner for the cold wet ensemble at 13 langleys in Shot 8, shown in Fig. 3.23, show that the most vulnerable spot is the upper chest, above the pockets. No indicators were placed there. Although the temperature indicators may show adequate protection for the locations measured, this does not insure

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that temperatures sufficient to cause injury were not reached in a few spots.

3.3.1 Hot Wet

Generally, the temperatures were from 48 to 106°C. At 5 langleys the highest temperature recorded was 62°C; at 13 langleys 106°C.

3.3.2 Hot Dry

The temperatures were slightly lower than for the Hot Wet ensemble, a maximum of 62°C at 5 langleys and 74°C for 13 langleys.

3.3.3 Temperature

The temperatures both with the jacket and the wool shirt were about the same as for the Hot Dry ensemble.

3.3.4 Cold Wet

The highest temperature recorded was 48°C and ~~only~~ that high in ONLY a few cases.

3.3.5 Cold Dry

The temperature was below that of the most sensitive indicator in all cases. Temperature indicators on the side of the face of the dummies equipped with hoods showed no consistent indication of high temperatures from the burning or melting ruff. At 4 langleys both sides may have reached as high as 48°C. At 10 langleys there were spotty indications of 56°C on the right side (nylon) and 118°C on the left side (fur). The temperatures here will depend very greatly on the contact with or proximity of ruff to skin as well as damage to the ruff.

3.3.6 Summary

The highest temperatures recorded were probably below the limit for second degree burns if the 141°C figure is accepted. However, the scorching of the dummies and underwear indicates that the maximum temperatures were above the maximum recorded. The hot dry and hot wet ensembles do not provide adequate protection at 10 to 13 langleys where there is only a single layer of the outer fabric but they do in multilayer

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areas, such as the pocket, collar and waist locations. The temperate, cold wet and cold dry ensembles afford adequate protection at 13 langleys.

With some modification to improve the protection in the upper chest area the above uncertainty would be eliminated for the front of the upper body. However, other areas are about equivalent to the upper chest. Exposures were not made on sleeves, backs or legs but they are equally vulnerable and would not offer adequate protection for radiation of this intensity at normal incidence.

Even though the heavier ensembles provide adequate protection at this level and probably at higher levels, it should be emphasized again that although the soldier would likely survive the atomic blast the outer clothing would be so severely damaged that it would not provide adequate environmental protection.

There are differences between the ensembles which would likely be greater at higher intensities. The hot dry ensemble was better than the hot wet. It is slightly heavier but likely most of the difference is due to its higher reflectance. The relatively light hot dry was nearly as good as the heavier temperate, again probably because of the higher reflectance. The very good protection of the cold wet and cold dry ensembles is mainly a matter of thickness and weight.

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TABLE 3.1

Clothing Ensembles

Fabric layers are in order, first layer exposed, last layer next to dummy

	Garment		Fabric			
Type	Name	Spec.	Name	Spec.	Nominal Weight oz/yd²	Shade
Hot Wet	Shot 6					
	Jacket, Light Weight	Experimental Model	Cl. Ctn. Permeable	MIL-C-10859A	5.2	OG-116
	Under Shirt, Ctn. Quarter Sleeve	JAN-U-797	Cl. Ctn. Knitted		3.0 8	White
	Shot 8					
	Jacket, Light Weight	MIL-J-3175	Cl. Ctn. Wind Resistant, Poplin	MIL-C-342A	6.5	OD-7
	Under Shirt, Ctn. Quarter Sleeve	JAN-U-797	Cl. Ctn. Knitted		3 9	White
Hot Dry	Shirt, Ctn. Stand-Up Collar, Khaki	MIL-S-3011-B-A-1	Cl. Ctn. Uniform Twill	JAN-C-298	8.2	Khaki I
	Under Shirt, Ctn. Quarter Sleeve	JAN-U-797	Cl. Ctn. Knitted		3.0 11	White
	Shot 6					
Temperate	Jacket Shell, M-1951	MIL-J-11448 (QMC)	Cl. Ctn. Wind Resistant, Sateen	MIL-C-557A	9	OG-107
			Cl. Ctn. Wind Resistant, Oxford	MIL-C-484	5.5	OG-107
	Shirt, Field, Wool	MIL-S-10858 (QMC)	Cl. Wool	MIL-C-10752	10.3	OG-108
	Undershirt, Winter, M-50	MIL-U-10211B	Cl. Wool & Cotton (50/50/Knitted)		10.5 35	Grey
	Shot 8					
	Shirt, Field, Wool	MIL-S-10858 (QMC)	Cl. Wool	MIL-C-10752	10.3	OG-108

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TABLE 3.1 (cont'd)

Clothing Ensembles

Fabric layers are in order, first layer exposed, last layer next to dummy

Type	Garment: Name	Garment: Spec.	Fabric: Name	Fabric: Spec.	Nominal Weight oz/yd²	Shade
	Undershirt, Winter, M-50	MIL-U-10211B	Cl. Wool & Cotton (50/50/Knitted)		10.5 / 21	Grey
Cold Wet	Jacket, Shell, Field	MIL-J-11448 (QMC)	Cl. Ctn. Wind Resistant, Sateen	MIL-C-557	9	OG-107
			Cl. Ctn. Wind Resistant, Oxford	MIL-C-484	5.5	OG-107
	Liner, Jacket, Field	MIL-L-11449 (QMC)	Cl. Rayon, Acetate (Saponified) Rip Stop	MIL-C-10772A	1.8	OD-7
			Cl. Mohair, Frieze Double Face	MIL-C-10751	17	White
	Shirt, Field, Wool	MIL-S-10858 (QMC)	Cl. Wool	MIL-C-10752	10.3	OG-108
	Under Shirt, Winter, M-50	MIL-U-10211B	Cl. Wool & Cotton (50/50) Knitted		10.5	Grey
Cold Dry	Parka Shell, M-1951	MIL-P-11013 (QMC)	Cl. Ctn. Warp, Nylon Filled, Oxford	MIL-C-10829	5.0	OG-107
	Parka Liner, M-51	MIL-P-11012 (QMC)	Cl. Rayon, Acetate (Saponified) Rip-Stop	MIL-C-10772A	1.8	OD-7
			Cl. Mohair, Frieze Double Face	MIL-C-10751	17	White
	Jacket, Shell, Field, M-1951	MIL-J-11448 (QMC)	Cl. Ctn. Wind Resistant, Sateen	MIL-C-557A	9	OG-107
			Cl. Ctn. Wind Resistant, Oxford	MIL-C-484	5.5	OG-107

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TABLE 3.1 (cont'd)

Clothing Ensembles
Fabric layers are in order, first layer exposed, last layer next to dummy

Type	Garment Name	Garment Spec.	Fabric Name	Fabric Spec.	Nominal Weight oz/yd²	Shade
	Liner, Jacket Field, M-1951	MIL-L-11449 (QMC)	Cl. Rayon, Acetate (Saponified) Rip-Stop	MIL-C-10772A	1.8	OD-7
			Cl. Mohair, Frieze, Double Face	MIL-C-10751	8.4	White
	Shirt, Field, Wool	MIL-S-10858 (QMC)	Cloth, Wool	MIL-C-10752	10.3	OG-107
	Under Shirt, Winter, M-50	MIL-U-10211B	Cl. Wool and Cotton (50/50) Knitted		10.5	Grey
	Hood, Parka, M-1951	MIL-H-11023	Cl. Ctn. Warp, Nylon Filled, Oxford	MIL-C-10829		OG-107
			Cl. Wool, Lining	MIL-C-2069		OD-33
			Fur Strips: one side Wolverine, one side Nylon	MIL-F-11861		

TABLE 3.2

Reflectance & Transmittance of Outer Layers of Clothing Fabrics. Averages for Visible & Near Infra Red Regions

Item	Ensemble	Shade	Reflectance, % V	Reflectance, % IR	Approx. transmittance, % V	Approx. transmittance, % IR
Jacket, Light Wt.	Hot Wet	OG-116	8. [a]	21.5[a]	2.5[b]	2.5[b]
" " "	" "	OD-7	7.5[a]	18. [a]		
Shirt, Uniform Twill	Hot Dry	Khaki I	25. [b]	62. [b]	1. [b]	12. [b]
Shirt, Wool, Flannel	Temperate	OG-108	6. [b]	19. [b]		
Jacket, Field	Temperate and Cold Wet	OG-107	6. [a]	15.5[a]	<0.5[b]	<0.5[b]
Parka	Cold Dry	OG-107	7.5[a]	17.5[a]	<0.5[b]	2. [b]

Note: If measured on garment, data are marked a; if on corresponding fabric, marked b.

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TABLE 3.3

Temperatures in Various Areas, Behind Clothing

Ensemble	Chest	Waist	Shoulder L	Shoulder R	Side L	Side R	Chest	Waist	Shoulder L	Shoulder R	Side L	Side R
	Temperature, °C											
Shot 6	1-1/2 miles, 4 cal/cm^2						1 mile, 10 cal/cm^2					
Hot Wet	48	48	48 62	56 62	<48	<48	62 68	74 106	56	62	56	48
Hot Dry	<48	<48	48	56 62	<48	<48	48 62	48 79	48 56	62 74	48	<48
Temperate	<48	48	48 56	56 62	<48	<48	48	48	56	56	<48	<48
Cold Wet	<48	<48	48	<48	<48	<48	<48	<48	<48	48	<48	<48
Cold Dry	<48	<48	<48	<48	<48	<48	<48	<48	<48	<48	<48	<48
Shot 8	1-1/2 miles, 5 cal/cm^2						1 mile, 13 cal/cm^2					
Hot Wet	48 56	<48	48	48 56	<48	<48	48 74	56 79	62 79[a]	62 79[b]	48	48 62
Hot Dry	62	<48	<48	<48	<48	<48	56 62	56 68	48	56 74		48
Temperate	<48	<48	48	48	<48	<48	74	<48	48	48	<48	<48
Cold Wet	<48	<48	<48	<48	<48	<48	<48	<48	<48	<48	<48	<48
Cold Dry	<48	<48	48	<48	<48	<48	<48	<48	<48	<48	<48	<48

a Spotty indications, 125 to 146°C, possibly from burning fabric
b " " 133 to 205°C, " " " "

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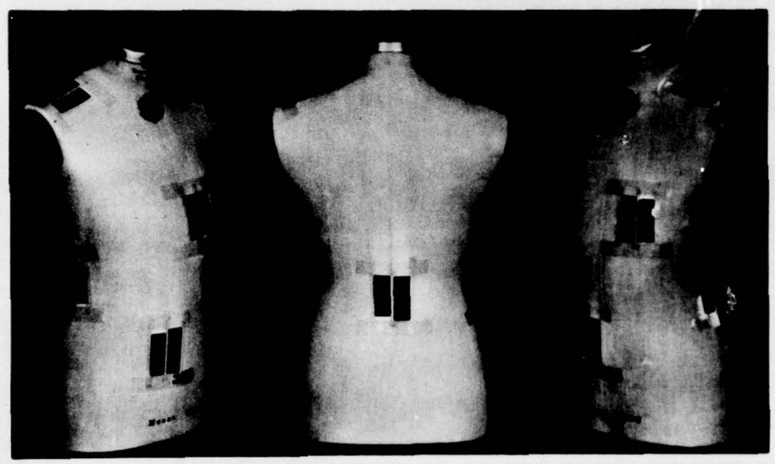

Fig. 3.1 Dummies with Temperature Indicators

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Fig. 3.2 Shot 6 - 1-1/2 Miles Hot Wet

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Fig. 3.3 Shot 6 - 1-1/2 Miles Hot Dry

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Fig. 3.4 Shot 6 - 1-1/2 Miles Cold Wet

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Fig. 3.5a Shot 6 - 1-1/2 Miles Cold Dry.
Before Exposure.

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Fig. 3.5 Shot 6 - 1-1/2 Miles Cold Dry

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Fig. 3.6 Shot 6 - 1 Mile Hot Wet

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Fig. 3.7 Shot 6 - 1 Mile Hot Dry

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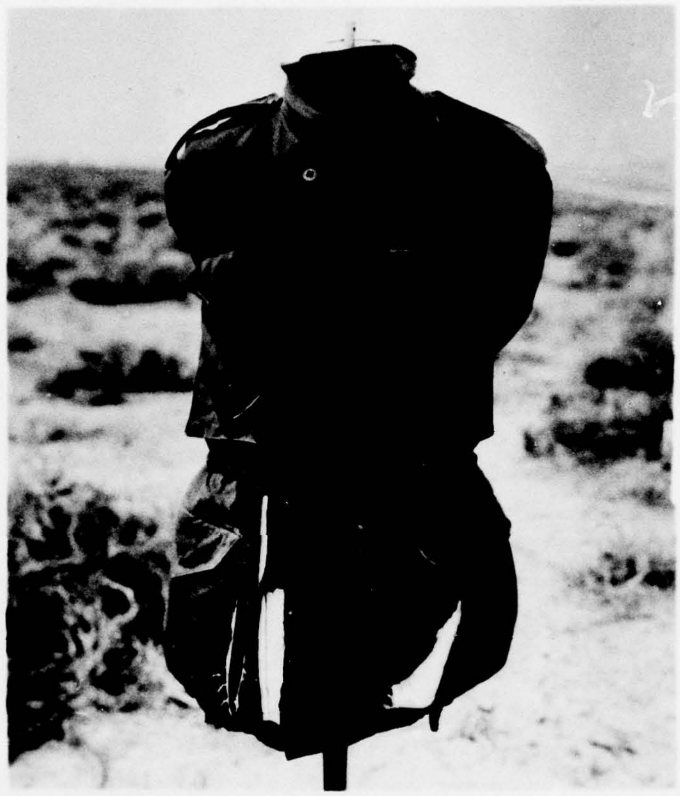

Fig. 3.8 Shot 6 - 1 Mile Temperate

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Fig. 3.9 Shot 6 - 1 Mile Cold Wet

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Fig. 3.10 Shot 6 - 1 Mile Cold Dry

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Fig. 3.11 Shot 8 - 1-1/2 Miles Hot Wet

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Fig. 3.12 Shot 8 - 1-1/2 Miles Hot Dry

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Fig. 3.13 Shot 8 - Before Exposure
Temperate

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Fig. 3.14 Shot 8 - 1-1/2 Miles Temperate

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Fig. 3.15 Shot 8 - 1-1/2 Miles Cold Wet

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Fig. 3.16 Shot 8 - 1-1/2 Miles Cold Dry

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Fig. 3.17 Shot 8 - 1 Mile Hot ~~Dry~~ WET

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Fig. 3.18 Shot 8 - 1 Mile Hot Dry

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[redacted]

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Fig. 3.19 - Shot 8 - 1 Mile Temperate

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Fig. 3.20 - Shot 8 - 1 Mile Cold Wet

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Fig. 3.21 Shot 8 - 1 Mile Cold Dry

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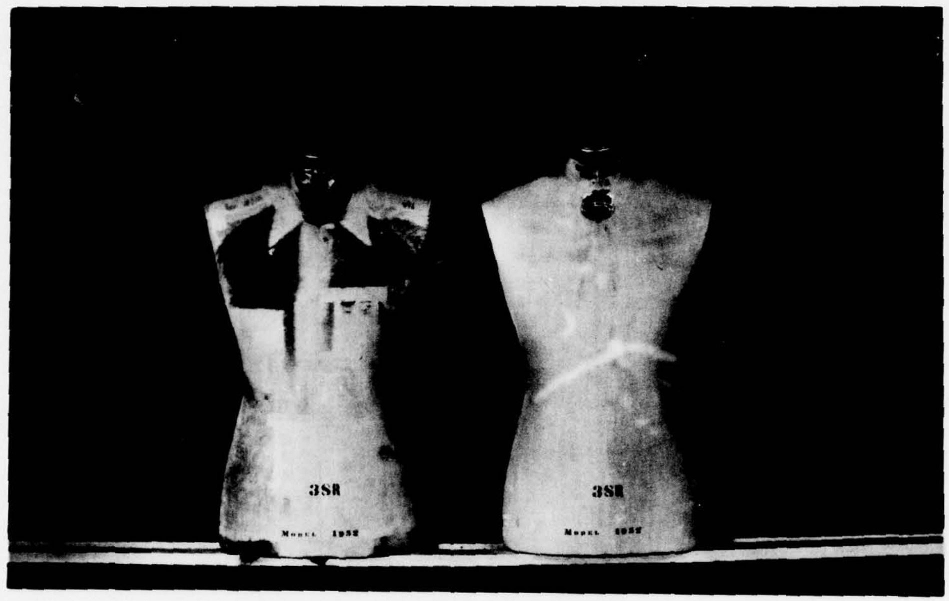

Fig. 3.22 Scorching of Dummies under Hot Wet and Hot Dry Ensembles, 1 Mile, Shots 6 & 8

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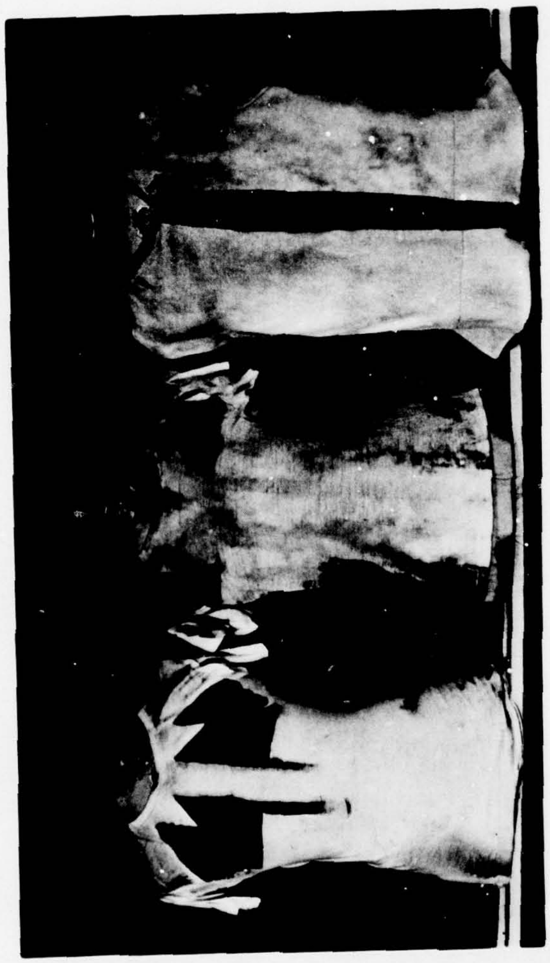

Fig. 3.23 Scorching of Under Layers, 1 Mile, Hot Wet Shot 6, Hot Wet Shot 8, Cold Wet Shot 8

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CHAPTER 4

FABRICS ON PANELS

4.1 PROCEDURE

The same clothing ensemble fabrics were exposed on flat panels and in addition other fabrics and combinations were used to determine the effect of reflectance, transmission, and spacing; the effect of blending wool with synthetic fibers, and the protective value of the cold bar ensemble.

4.1.2 Method of Mounting

The panels were the same type used in Operation Buster[2]. They were of white pine about 8 in. square with about half the sample in contact with the backing and the other half spaced 1/4 in. from the backing. The backing had a reflectance of about 56 percent in the visible and 93 percent in the near infrared. In this experiment the wood panel was backed with 1/4 in. plywood. The samples were mounted on an angle iron frame with about 2 in. spacing between samples. These are shown in Fig. 4.1. The frame was adjusted for normal incidence.

To measure the protective value, the passive indicators described in Section 2.5 were placed behind the fabrics.

4.2 FABRICS

For each shot there were 16 samples; these were not exactly the same for the two shots. They are listed in Table 4.1, which also gives some properties of the fabrics including weight and average reflectance and transmittance. The reflectance and transmittance are also shown in Figs. 2.1, 2.2 and 2.3. The repeated values in Table 1 represent a measurement on a single sample of the fabric.

4.3 DAMAGE TO FABRICS

4.3.1 Photographs

Photographs of the panels are shown in Figs. 4.1 to 4.4. With few exceptions there was little or no damage at 5 langleys and the materials before exposure were essentially the same as after exposure at 1-1/2 miles.

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4.3.2 Damage Code

For convenience in recording a code of damage was used; it was about the same as that in Operation Ranger and is given below.

Rating	Damage to each surface
0	No perceptible damage
1	Barely perceptible damage cotton - very slightly scorched; wool and blends of wool with synthetics - singed.
3	Appreciable damage cotton - very definite scorches; wool and wool blends - singed and trace of melting.
5	Severe damage cotton - badly scorched and beginning of charring; wool and wool blends - melted.
7	Very severe damage cotton - charred, dark brown; wool and wool blends - melted, little or no trace of weave pattern.
9	Extreme damage cotton - charred very dark brown or black; wool and wool blends - thick layer on surface melted and dark in color.

Rating	Overall Damage
0	No perceptible damage, intact.
1	Slightly torn or burned, almost intact.
3	Considerable tearing or burning, up to half of sample gone.
5	More than half gone.
7	Nearly all gone.
9	All gone.

The rating then includes 3 digits, the first for the face, the second for the reverse side and the third overall; e.g., a rating of 000 indicates no perceptible damage at all; 955 indicates extreme damage

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on the face, severe damage on the reverse side and more than half the sample missing. Where the sample was missing or so little left that the thermal damage could not be estimated, that is indicated by - - 9.

4.3.3 <u>Damage at Low ~~Intensities~~</u> Radiant Exposures.

There was very little damage at 4 to 5 langleys. The only visible effect was on the following:

Sample 5, some damage to the nylon of the cotton warp-nylon filled oxford, rating 111.

Samples 13, 14, 15, 16 and 17, serges of wool and blends of wool and synthetics, slight singeing, with ratings of 100.

Samples 18 and 19, Orlon, heat treated, slight shininess, rating 100.

4.3.4 <u>Damage at 10 to 13 Langleys</u>

The damage at 10 and 13 langleys is summarized in Table 4.2.

4.3.4.1 <u>Fabrics Equivalent to Clothing Ensembles</u>

The damage to fabrics on the panels was about the same as the maximum damage to the same fabrics as clothing. The nylon filled cotton warp oxford on sample 5 was slightly damaged at 5 langleys and completely destroyed at 13 langleys.

4.3.4.2 <u>Reflectance</u>

The undyed sateen, sample 10, was much more resistant than either OD-7 or OG-107 with no perceptible damage at 13 langleys. Dyed samples were almost completely destroyed at that intensity. The aluminized fabric showed no damage up to 10 langleys.

There were slight but apparently definite differences between standard and camouflage shades. For cotton, OG-107, e.g., sample 8, was damaged more than OD-7, sample 9. For wool, OG-108, sample 13, was damaged more than OD-33, sample 14.

4.3.4.3 <u>Backing and Under Layers</u>

The spaced samples; i.e., with air backing, were damaged

Fabrics with air backing were damaged more than those in contact. Under layers were scorched more for the contact condition than for the spaced arrangement. The damage to the surface fabric in multi-layer systems was about the same as for contact with a wood backing.

The damage to fabrics exposed as clothing varied considerably but the maximum damage was similar to that of fabrics on flat panels.

Whenever comparisons are possible the results here are in agreement with the results of previous tests or with principles evident from those tests.

4.4 PROTECTIVE VALUE OF FABRICS

The temperatures shown by the indicators behind the fabrics are given in Table 4.3. As is the usual experience with these indicators, generally the indication is not a single temperature but a range of temperatures. The first figure is the highest temperature for which the change was complete; the second figure is the highest for which there was any definite indication of change. Generally this range is sufficiently small to give useful results. For similar sample, for which a direct comparison is desirable, visual examination will sometimes show differences not necessarily obvious in the table; i.e., it is possible to determine a difference between fabrics even though that difference cannot be expressed qualitatively.

Generally, the temperatures were higher for the higher ~~intensities~~ energies and lower for the spaced sample than for contact. Comparisons between fabrics must be made under comparable conditions.

4.4.1 Fabrics Equivalent to Clothing Ensembles

The temperatures were highest for Sample 1, the hot wet combination of 5.2 oz. cotton permeable and light weight underwear, with temperatures up to 106°C at 5 langleys and up to 223°C at 13 langleys. They were considerably lower for sample 2, the hot dry combination of 8.2 oz. khaki uniform twill and light weight underwear, up to 180°C at 13 langleys. The twill is slightly heavier than the permeable but most of the difference is in reflectance, an average of about 40 percent for the khaki compared to about 15 percent for the permeable. For sample 3, the combination of 9 oz. sateen, 10.3 oz. wool flannel and 10.5 oz. winter undershirt, there was considerable variation in protection with intensity. At low intensities this combination was better than Sample 2 but at 15 cal. per sq. cm. it was not. The effects of weight and reflectance can be balanced but the balance seems to depend on inten ity. For samples 4 and 5, corresponding approximately to the cold wet and cold dry

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ensembles, the maximum temperature was 56°C and generally the lowest indicators were just on the verge of changing.

4.4.2 Effect of Reflectance

Samples 8, 9 and 10 are of the same basic fabric, 9 oz. W.R. sateen; sample 10 undyed, sample 9 dyed with the old standard OD-7 and sample 8 dyed with the current standard OG-107. The average reflectances are about

	Visible	Near Infrared
Undyed	69.	83.
OD-7	9.5	26.
OG-107	6.5	18.

Up to 1.0μ the OD-7 and OG-107 samples transmit very little light; the value for the undyed fabric is roughly 15 percent.

Temperatures were generally slightly hotter for the OG-107 than for OD-7 as indicated below:

Exposure ~~Intensity~~	Contact		Spaced	
langleys	OD-7	OG-107	OD-7	OG-107
6	68-92	79-106	62	62
6	74-106	68-133	56-62	62
15	133-223	146-257	100-175	146-257
15	157-257	133-257	125-257	146-240

The differences are small but apparently definite and in accordance with the differences in reflectance and in agreement with the results of Operation BUSTER[1].

The undyed fabric was exposed only on Shot 8. For that case the temperatures were generally higher than for the corresponding dyed fabrics. At 5 langleys, in contact the protection was about the same as for OG-107 but spaced it was considerably less; at 13 langleys the temperatures were very high, for both contact and spaced. This lower protection afforded by undyed fabrics and especially the lack of difference between contact and spaced fabrics is also in agreement with results of Operation BUSTER[1].

4.4.3 Transmittance of Under Layers

If any appreciable part of the energy transferred to the backing by radiation, possibly from hot fabric, it might be expected that

the transmittance of underlying layers would be important. The difference between samples 11 and 12 is in the color of the frieze, undyed for sample 11 and OG-108 for sample 12. There is little difference in protection but apparently the undyed frieze was consistently slightly better. Possibly the difference in effective transmission is very small or the effects of differences in transmittance were overshadowed by differences in structure, thickness and conductivity effected in the dyeing process.

4.4.4 Blends of Fibers

In samples 13 to 16 the yarns are blends of wool with 15 or 30 percent of various synthetic fibers. There is little difference between the various blends and probably the protection is about the same as for all wool.

4.4.5 Orlon

There was sufficient heat treated orlon for exposure on only one shot. The temperatures were approximately the same as for the 9 oz. sateen OG-107.

4.4.6 Aluminized Fabrics

Possibly the most outstanding result was the protection afforded by a single layer of aluminized cotton drill, 7 oz. per sq. yd. The maximum temperatures at 15 langleys were 62° in contact and 56° spaced. The corresponding values for 9 oz. sateen are 50 to 200°C higher. Apparently the high reflectance and low transmittance are the important factors in providing this protection. When this aluminized surface was covered with a layer of orlon, with a total weight of 15.[illegible] oz. per sq. yd. the protection was considerably less, with temperatures up to twice that for the unprotected aluminum surface. Unfortunately it does not seem possible to retain the advantage of high reflecting layers if they must be camouflaged.

4.4.7 Order of Layers and Location of Spacing

The contact side of sample 22 was the same as sample 4 with the exception that the order was reversed; i.e., the underwear was out and the 9 oz. W.R. sateen in contact with the backing. The temperatures were about the same for the two cases.

The spaced side of sample 22 was the same as sample 4 except

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the space was between the flannel and undershirt and the undershirt was in contact with the backing. Again the results are about the same for the two cases.

For both samples the intensity was too low to show any differences that may have existed.

4.4.8 Spacing

Previous tests as well as the current one showed that for opaque fabrics, the protection was considerably greater if the fabric were spaced from the backing. However, all the results were at a single fixed spacing of 1/4 inch. In sample 21 the spacing was 1/16 and 1/2 inch. There was a definite dependence of temperature on spacing. The values for samples 8 and 21 are listed below:

	Spacing			
	0 (contact)	1/16 in.	1/4 in.	1/2 in.
6 langleys	68-133	62- 79	62	48
15	133-257	146-257	146-240	100-180

For the low ~~intensity~~ energy there is a considerable drop from contact to a very small spacing and also a continuing decrease up to 1/2 in. spacing. At the higher ~~intensity~~ energy level there is little difference between contact and a 1/4 in. spacing but a definite drop between 1/4 and 1/2 in.

4.4.9 Summary

The temperatures were higher for clothing fabrics on flat panels than for the corresponding ensembles on dummies. To a large extent this resulted from differences in contact between layers and between fabric and backing and to variations in the angle of incidence. To some extent the difference was due to variations in weight of fabric since the panels were not exactly like the clothing. They did not include extra thicknesses at folds, seams, plaits and pockets.

The temperatures behind the cold bar combination were approximately the same as for the cold wet fabric combination, possibly just slightly higher.

There were differences due to reflectance and fabric weight, generally in agreement with previous results and with expectations from laboratory studies. The temperatures with camouflage shades were just slightly higher than with standard shades, for both cotton and wool. The undyed fabric did not provide good protection. On the other hand, the aluminized fabric probably gave the best protection of any fabric tested

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here previously, for a corresponding weight. The transmittance of underlying layers did not seem to have any influence on the temperature. The orlon fabric did not provide outstanding protection. Blends of wool and synthetics, at least up to 15 percent, were as good as all wool.

In a single test there was no effect of varying the order of layers nor varying the location of a single spacing between layers. There was a definite effect of increasing the spacing with a continuous decrease in temperature from 1/16 to 1/2 inch spacing.

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TABLE 4.1

Fabric Samples for Panel Tests
Fabrics are in order with First Layer Exposed, Last Layer next to Backing

Sample No.	Nomenclature	Nominal Weight oz/yd²	Shade	Reflectance % V	Reflectance % IR	Transmittance % V	Transmittance % IR	Spec. No. or Laboratory Designation
	Hot Wet							
1	Cl. ctn. Oxford, permeable	5.2	OG-116	8.0	21.5	2.5	7.5	MIL-C-10859B
	" " knitted (light weight undershirt)	3	White	69.5	78.5	34.	36.	JAN-U-797
		8						
	Hot Dry							
2	Cl. ctn. uniform twill	8.2	Khaki I	25.	62.	1.	12.	JAN-C-298
	" " knitted (light weight undershirt)	3	White	69.5	78.5	34.	36.	JAN-U-797
		11						
	Temperate							
3	Cl. ctn. wind resistant sateen	9	OG-107	7.	17.5	<0.5	<0.5	MIL-C-557A
	Cl. wool flannel	10.3	OG-108	5.5	14.5			MIL-C-10752
	Cl. wool & ctn. knitted (winter undershirt)	10.5	Grey	55.	75.	12.5	20.	MIL-U-10211B
		30						
	Cold Wet							
4	Cl. ctn. wind resistant sateen	9	OG-107	7.	17.5	< 0.5	< 0.5	MIL-C-557A
	Cl. Mohair, frieze	17	White	51.5	69.5	15.	21.5	MIL-C-10751
	Cl. rayon, rip-stop	1.8	OD-7	12.5	67.5	7.	32.5	MIL-C-10772a
	Cl. wool, flannel	10.3	OG-108	5.5	14.5			MIL-C-10752
	Cl. ctn. & wool, knitted (winter undershirt)	10.5	Grey	55.	75.	12.5	20	MIL-U-10211b
		49						
	Cold Dry							
5	Cl. ctn. warp, nylon filled oxford	5	OG-107	7.5	16.	<0.5	2.	MIL-C-10829

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TABLE 4.1 (cont'd)

Fabric Samples for Panel Tests
Fabrics are in order with First Layer Exposed, Last Layer next to Backing

Sample No.	Nomenclature	Nominal Weight oz/yd²	Shade	Reflectance % V	Reflectance % IR	Transmittance % V	Transmittance % IR	Spec. No. or Laboratory Designation
	Cl. mohair, frieze	17	White	51.5	69.5	15.	21.5	MIL-C-10751
	Cl. rayon, rip stop	1.8	OD-7	12.5	67.5	7.	32.5	MIL-C-10772A
	Cl. ctn. wind resistant, sateen	9	OG-107	6.5	17.5		0.5	MIL-C-557A
	Cl. Mohair, Frieze	17	White	51.5	69.5	15.	21.5	MIL-C-10751
	Cl. rayon, rip stop	1.8	OD-7	12.5	67.5	7.	32.5	MIL-C-10772A
	Cl. wool, flannel	10.3	OG-108					MIL-C-10752
	Cl. wool & ctn. knitted (winter undershirt)	10.5 / 72	Grey	55.	75.	12.5	20	MIL-U-10211B
6	Cl. ctn. wind resistant, sateen	9	OG-107	7.	17.5	<0.5	<0.5	MIL-C-557A
	Cl. mohair, frieze	17	White	51.5	69.5	15.	21.5	MIL-C-10751
	Cl. rayon, rip stop	1.8	OD-7	12.5	67.5	7.	32.5	MIL-C-10772A
	Cl. ctn. wind resistant sateen	9	OG-107	6.5	17.5		0.5	MIL-C-557A
	Cl. mohair, frieze	17	White	51.5	69.5	15.	21.5	MIL-C-10751
	Cl. rayon, rip stop	1.8	OD-7	12.5	67.5	7.	32.5	MIL-C-10772A
	Cl. wool, flannel	10.3	OG-108	5.5	14.5			MIL-C-10752
	Cl. wool & ctn. knitted (winter under shirt)	10.5	Grey	55.	75.	12.5	20	MIL-U-10211B
7	Cl. ctn. wind resistant, sateen (Cold bar)	9	OG-107	7.	17.5	<0.5	<0.5	MIL-C-557A
	Plastic, expanded, unicellular, elastomeric (Insulite) (cold bar)	31[a] / 40						MIL-P-12420

a. About 9/32 in. thick, density about 5.1 lbs/ft^3.

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TABLE 4.1 (cont'd)

Fabric Samples for Panel Tests
Fabrics are in order with First Layer Exposed, Last Layer next to Backing

Sample No.	Nomenclature	Nominal Weight oz/yd^2	Shade	Reflectance % V	Reflectance % IR	Transmittance % V	Transmittance % IR	Spec. No. or Laboratory Designation
8	Cl. ctn. wind resistant sateen	9	OG-107	7.	17.5	<0.5	<0.5	MIL-C-557A
9) 9a)	Cl. ctn. wind resistant sateen	9	OD-7	9.5	26.0	<0.5	<0.5	MIL-C-557A
10	Cl. ctn. wind resistant sateen	9	White	69.	82.5	12.5	18	MIL-C-557A
11	Cl. ctn. wind resistant sateen	9	OG-107	7.	17.5	<0.5	<0.5	MIL-C-557A
	Cl. mohair, frieze	17/26	White	51.5	69.5	15.	21.5	MIL-C-10751
12	Cl. ctn. wind resistant sateen	9	OG-107	6.5	17.5	<0.5	<0.5	MIL-C-557A
	Cl. Mohair, frieze	17/26	OD-7	8.5	57.5	0.5	12.5	MIL-C-10751
13	Cl. wool, serge	11.6	OG-108	5.5	14.5		0.5	J.P. Stevens
14	Cl. wool, serge	11.6	OD-33	12.	45.		12.5	MIL-C-11305 QMC. Living-ston Pc. 7412
15	Cl. 70% wool, 30% dacron	11.6	OD-33	8.0	44.5			
16	Cl. 85% wool, 15% nylon	11.6	OG-108	6.5	30.			

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TABLE 4.1 (cont'd)

Fabric Samples for Panel Tests
Fabrics are in order with First Layer Exposed, Last Layer next to Backing

Sample No.	Nomenclature	Nominal Weight oz/yd²	Shade	Reflectance % V	Reflectance % IR	Transmittance % V	Transmittance % IR	Spec. No. or Laboratory Designation
17	Cl. 85% wool, 15% dynel	11.6	OD-33	8.5	46.			
18	Cl. orlon, spun, heat treated	8.3	black	4.	3.5	<0.5	<0.5	Johns-Manville
19	Cl. ctn. twill, aluminized	7.0	alum.	74.	74.	1.	2.5	National Research Corp.
20	Cl. orlon, spun, heat treated	8.3	black	4.	3.5	<0.5	<0.5	Johns-Manville
	Cl. ctn. twill, aluminized	7.0	alum.	74.	74.	1.	2.5	National Research Corp.
21	Spacing sample - 1/16 & 1/2 in.							
	Cl. ctn. wind resistant sateen	9	OG-107	7.	17.5	<0.5	<0.5	MIL-C-557A
22	Composite layer sample							
	a. space between shirt & undershirt, undershirt in contact							
	cl. ctn. wind resistant	9	OG-107	7.	17.5	<0.5	<0.5	MIL-C-557A
	cl. mohair, frieze	8.4	White	51.5	69.5	15.	21.5	MIL-C-10751
	cl. rayon, rip stop	1.8	OD-7	12.5	67.5	7.	32.5	MIL-C-10772A
	cl. wool, flannel	10.3	OG-108	5.5	14.5			MIL-C-10752
	1/4 in. space							
	Cl. wool & ctn. underwear, knitted (winter undershirt)	10.5	Grey	55.	75.	12.5	20.0	MIL-U-10211B

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TABLE 4.1 (cont'd)

Fabric Samples for Panel Tests
Fabrics are in order with First Layer Exposed, Last Layer next to Backing

Sample No.	Nomenclature	Nominal Weight oz/yd^2	Shade	Reflectance % V	Reflectance % IR	Transmittance V	Transmittance IR	Spec. No. or Laboratory Designation
	b. Contact							
	Same fabrics in reverse order, no space	40						Same

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TABLE 4.2

Damage to Fabrics on Panels
Damage Code in Section 4.4

Sample No.	Description	Nominal Weight oz/yd^2	Shade	Damage Rating: Shot 6, 10 langleys, C	Damage Rating: Shot 6, 10 langleys, S	Damage Rating: Shot 8, 13 langleys, C	Damage Rating: Shot 8, 13 langleys, S
1	Cotton, permeable	5.2	OG-116	997	999	--9	--9
	Light weight undershirt	3	White	310	310	511	311
2	Cotton, uniform twill	8.2	Khaki I			731	731
	Light weight undershirt	3	White			310	310
3	Cotton, WR sateen	9	OG-107	731	751	999	999
	Wool flannel	10.3	OG-108	310	310	300	300
	Winter undershirt	10.5	Grey	100	100	100	100
4	Cotton, WR Sateen	9	OG-107	733	733	999	--9
	Mohair frieze	17	White	610	510	510	510
	Rayon lining	1.8	OD-7	000	000	000	000
	Wool flannel	10.3	OG-108	000	000	000	000
	Winter undershirt	10.5	Grey	000	000	000	000
5	Cotton warp nylon filling oxford	5	OG-107			--9	--9
	Mohair frieze	17	White			510	510
	Rayon lining	1.8	OD-7			000	000
	Cotton, WR sateen	9	OG-107			000	000
	Mohair frieze	17	White			000	000
	Rayon lining	1.8	OD-7			000	000
	Wool flannel	10.3	OG-108			000	000
	Winter undershirt	10.5	Grey			000	000
6	Cotton, WR sateen	9	OG-107	711	713		
	Mohair frieze	17	White	410	310		
	Rayon lining	1.8	OD-7	000	000		

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TABLE 4.2 (cont'd)

Damage to Fabrics on Panels
Damage Code in Section 4.4

Sample No.	Description	Nominal Weight oz/yd^2	Shade	Damage Rating: Shot 6, 10 langleys C	Damage Rating: Shot 6, 10 langleys S	Damage Rating: Shot 8, 13 langleys C	Damage Rating: Shot 8, 13 langleys S
	Cotton, WR sateen	9	OG-107	000	000		
	Mohair frieze	17	White	000	000		
	Rayon lining	1.8	OD-7	000	000		
	Wool flannel	10.3	OG-108	000	000		
	Winter undershirt	10.5	Grey	000	000		
7	Cotton, WR sateen	9	OG-107	731	731	999	999
	Insulite			300	300	300	300
8	Cotton, WR sateen	9	OG-107	731	731	997	--9
9	Cotton, WR sateen	9	OD-7	511	531	976	--9
9a	Cotton, WR sateen	9	OD-7			955	975
10	Cotton, WR sateen	9	White			000	000
11	Cotton, WR sateen	9	OG-107	731	731		
	Mohair Frieze	17	White	310	310		
12	Cotton, WR sateen	9	OG-107	731	751		
	Mohair Frieze	17	OG-108	500	500		
13	Wool serge	11.6	OG-108	701	701	907	907
14	Wool serge	11.6	OD-33	900	700	705	905
15	70% wool, 30% dacron, serge	11.6	OD-33	701	701	955	955

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TABLE 4.2 (cont'd)

Damage to Fabrics on Panels
Damage Code in Section 4.4

Sample No.	Description	Nominal Weight oz/yd2	Shade	Damage Rating: Shot 6, 10 langleys, C	Shot 6, 10 langleys, S	Shot 8, 13 langleys, C	Shot 8, 13 langleys, S
16	85% wool, 15% nylon serge	11.6	OG-108			911	912
17	95% wool, 15% dynel serge	11.6	OD-33			903	903
18	Orlon, heat treated	8.3	Black	501	500		
19	Cotton twill, aluminized	7.0	Alum.	100	100		
20	Orlon, heat treated	8.3	Black	500	500		
	Cotton twill, aluminized	7.0	Alum.	100	100		
21	Cotton WR sateen, 1/16 in. space						--9
	1/2 in. space						--9
22	**Contact**						
	Winter underwear	10.5	Grey	100			
	Wool flannel	10.3	OG-108	000			
	Rayon lining	1.8	OD-7	000			
	Mohair frieze	8.4	White	000			
	Cotton WR sateen	9.	OG-107	000			
	Spaced						
	Cotton WR sateen	9.	OG-107		751		
	Mohair Frieze	8.4	White		310		
	Rayon lining	1.8	OD-7		000		
	Wool flannel	10.3	OG-108		000		
	1/4 in. space						
	Winter underwear, in contact	10.5	Grey		000		

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TABLE 4.3

Temperatures Behind Fabrics on Panels

Sample No.	Description	Nominal Weight oz/yd²	Shade	Temperature, °C Shot 6 4 langleys C		4 langleys S		10 langleys C		10 langleys S	
1	Cotton, permeable		OD-7	68	106	62		133	223	74	118
	Light weight undershirt	3	White								
		9									
2	Cotton, uniform twill	8.2	Khaki I								
	Lightweight undershirt	3	White								
		11									
3	Cotton, WR sateen	9	OG-107								
	Wool flannel	10.3	OG-108	56	62	56	62	56	68	56	
	Winter undershirt	10.5	Grey								
		30									
4	Cotton, WR sateen	9	OG-107								
	Mohair frieze	17	White								
	Rayon lining	1.8	OD-7	56		48		56		56	
	Wool, flannel	10.3	OG-108								
	Winter undershirt	10.5	Grey								
		49									
5	Cotton warp, nylon filling oxford	5	OG-108								
	Mohair frieze	17	White								
	Rayon lining	1.8	OD-7								
	Cotton, WR sateen	9	OG-107								
	Mohair frieze	17	White								
	Rayon lining	1.8	OD-7								
	Wool flannel	10.3	OG-108								
	Winter undershirt	10.5	Grey								
		72									

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TABLE 4.3 (cont'd)

Temperatures Behind Fabrics on Panels

Sample No.	Description	Nominal Weight oz/yd²	Shade	Temperature, °C Shot 6 4 langleys C		S		10 langleys C		S	
6	Cotton, WR sateen	9	OG-107								
	Mohair frieze	17									
	Rayon lining	1.8									
	Cotton, WR sateen	9									
	Mohair frieze	17			48		56	48		48	
	Rayon lining	1.8									
	Wool flannel	10.3									
	Winter undershirt	10.5									
		76									
7	Cotton, WR sateen	9	OG-107	48		56		62		56	
	Insulite										
8	Cotton, WR sateen	9	OG-107	79	106	62		146	257	146	257
9	Cotton, WR sateen	9	OD-7	68	92	62		133	223	100	175
9a	Cotton, WR, sateen	9	OD-7								
10	Cotton, WR sateen	9	White								
11	Cotton, WR sateen	9	OG-107	48		48	56	56	62	62	
	Mohair frieze	8.4	White								
		17									
12	Cotton, WR sateen	9	OG-107	56		62		62	68	62	
	Mohair frieze	8.4	OG-108								
		17									

TABLE 4.3 (cont'd)

Temperatures Behind Fabrics on Panels

Sample No.	Description	Nominal Weight oz/yd^2	Shade	Temperature, °C Shot 6 4 langleys C		4 langleys S		10 langleys C		10 langleys S	
13	Wool, serge	11.6	OG-108	68	79	62	68	100	180	100	146
14	Wool, serge	11.6	OD-33	68	84	62	74	106	157	100	146
15	70% wool, 30% dacron, serge	11.6	OD-33	62	79	62	74	100	146	100	106
16	85% wool, 15% nylon, serge	11.6	OG-108								
17	85% wool, 15% dynel, serge	11.6	OD-33								
18	Orlon, heat treated	8.3	Black	74	92	62	68	146	257	146	223
19	Cotton, twill, aluminized	7.0	Alum.	48		48		48	62	48	56
20	Orlon, heat treated	8.3	Black	68	106	62		84	180	62	68
	Cotton twill, aluminized	7.0	Alum.								
21	Cotton, WR sateen, 1/16" space	9	OG-108								
	1/2" space	9	OG-108								
22	Composite										
	Contact										
	Winter underwear	10.5	Grey								
	Wool, flannel	10.3	OG-108								
	Rayon, lining	1.8	OD-7	48	62			48			
	Mohair frieze	8.4	White								
	Cotton, WR sateen	9.	OG-107								
		40									

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TABLE 4.3 (cont'd)

Temperatures Behind Fabrics on Panels

Sample No.	Description	Nominal Weight oz/yd²	Shade	Temperature, °C Shot 6 4 langleys C	4 langleys S	10 langleys C	10 langleys S
	Spaced						
	Cotton, WR sateen	9.	OG-107				
	Mohair frieze	8.4	White				
	Rayon lining	1.8	OD-7		48 62		56
	Wool, flannel	10.3	OG-108				
	1/4 in. space						
	Winter underwear	10.5	Grey				
		40					

Sample No.	Description	Nominal Weight oz/yd²	Shade	Temperature, °C Shot 8 5 langleys C	5 langleys S	13 langleys C	13 langleys S
1				68 106	74	161 223	161 223
2				62 74	68	118 180	68 118
3				< 48	<48	62 68	48
4				< 48	< 48	<48	<48
5				< 48	< 48	< 48	<48
6							
7				<48	<48	48	48
8				68 133	62	133 257	146 240

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TABLE 4.3 (cont'd)

Temperatures Behind Fabrics on Panels

Sample No.	Description	Nominal Weight oz/yd^2	Shade	Temperature, °C Shot 8 5 langleys C		5 langleys S		13 langleys C		13 langleys S	
9				74	106	56	62	146	257	146	257
9a				68	106	48	56	157	257	157	257
10				79	118	74	146	180	257	161	257
11											
12											
13				68	84	48	62	100	180	100	146
14				74	92	62	92	146	180	118	180
15				74	84	50	79	146	223	146	161
16				68	92	56	79	118	223	118	157
17				68	84	56	74	118	223	100	146
18											
19											
20											
21	Cotton, WR Sateen, 1/16" space	9	OG-108			62	79			146	257
	1/2" space	9	OG-108				48			100	205
22											

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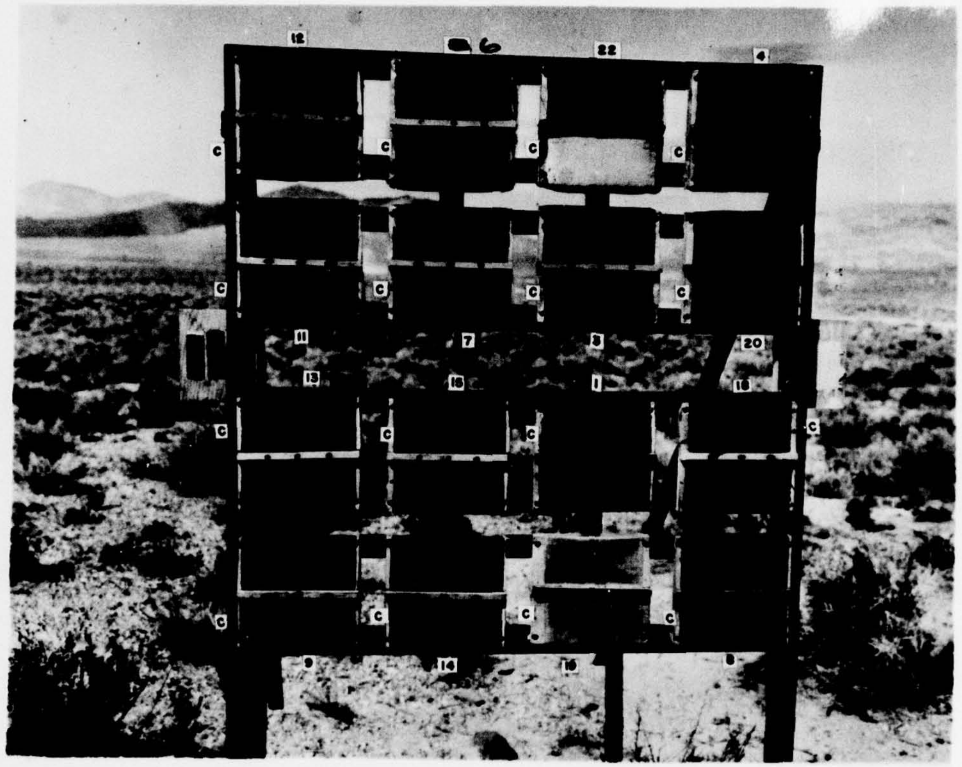

Fig. 4.1 Fabrics on Panels - Shot 6 - 1-1/2 Miles

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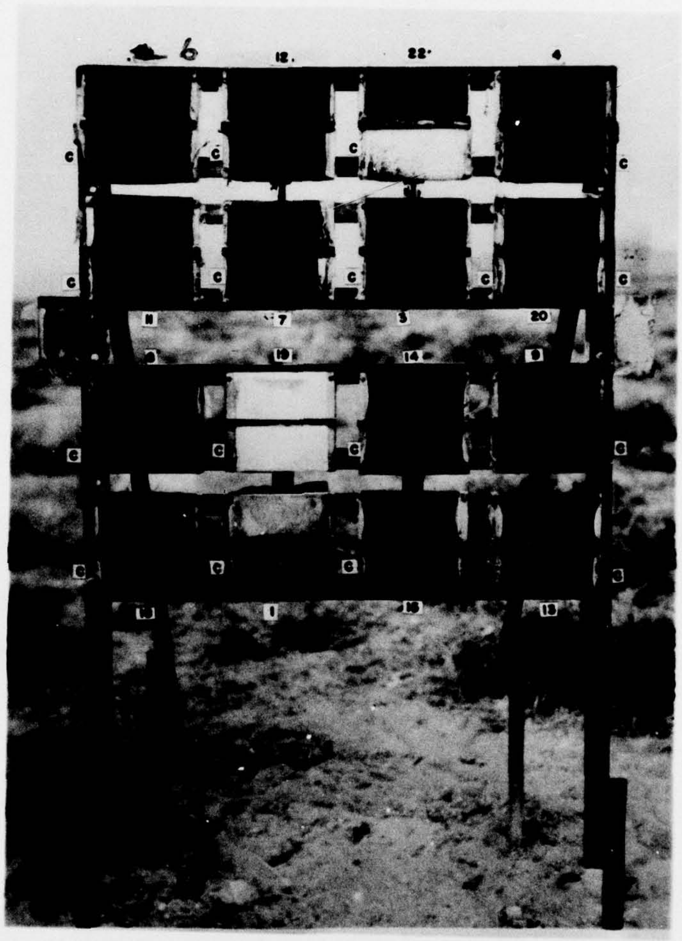

Fig. 4.2 Fabrics on Panels, Shot 6, 1 Mile

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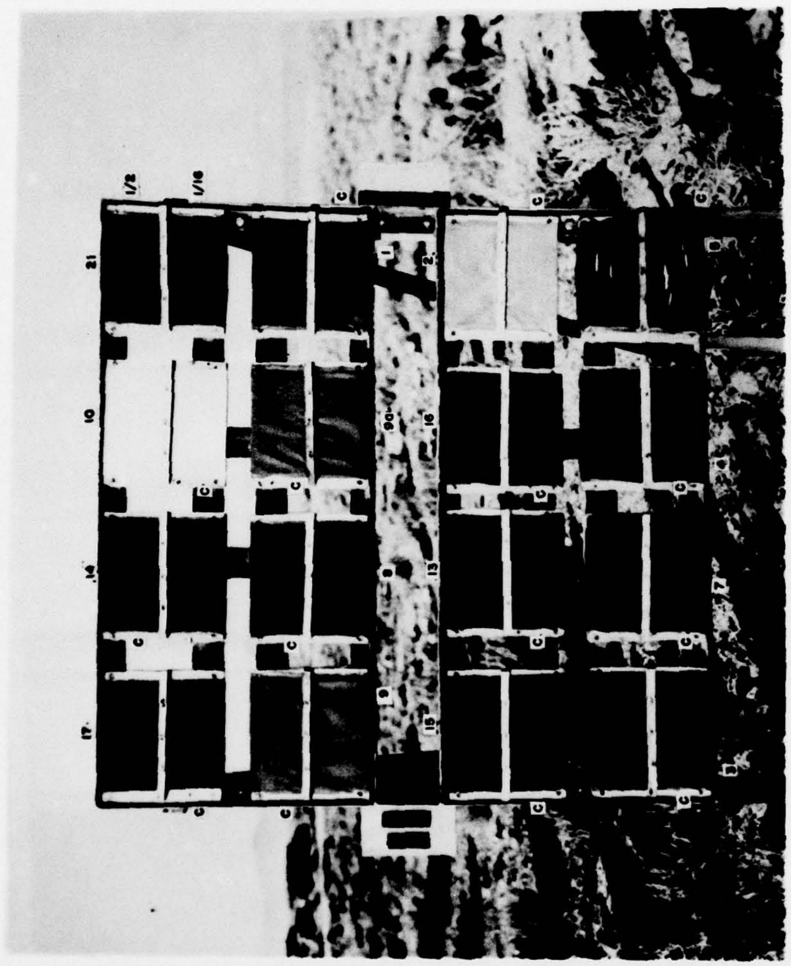

Fig. 4.3 Fabrics on Panels Shot 8, 1-1/2 Miles

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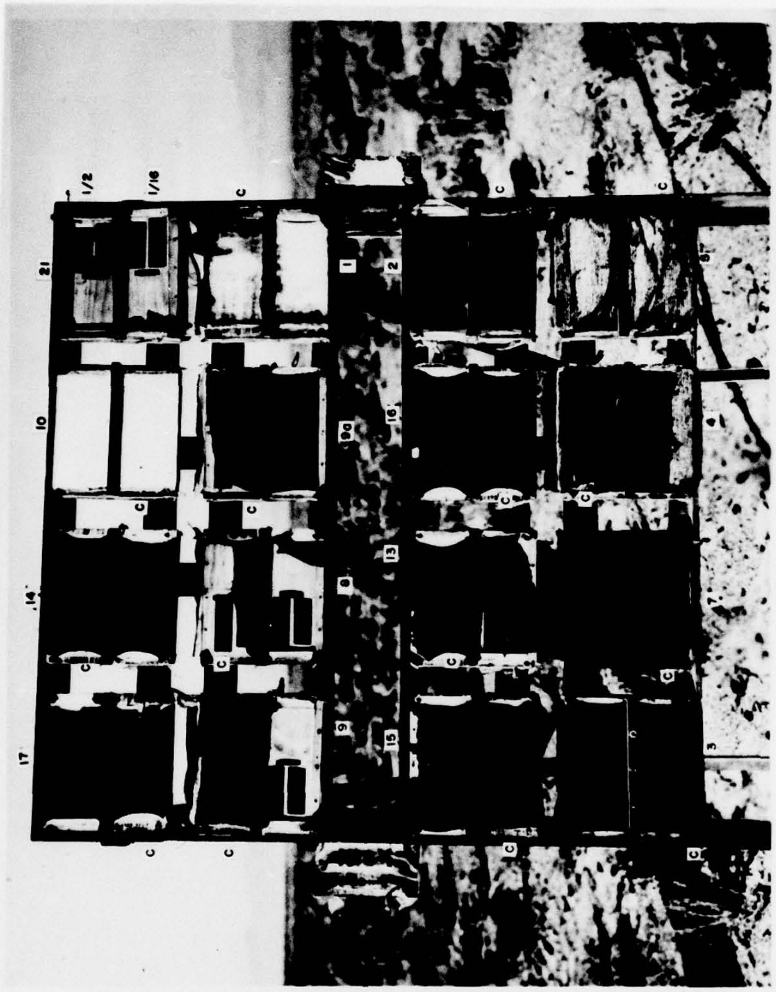

Fig. 4.4 Fabrics on Panels, Shot 8, 1 Mile

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CHAPTER 5

PROTECTIVE CREAM

5.1 GENERAL

The QM Cream, Protective, Flash Burn, described in Purchase Description, 16 January 1952, was tested in 3 thicknesses, from a very thin layer to 1/16 inch thick. The protective value was measured with the temperature indicators described in Section 2.3. Samples were exposed at about 1 and 1-1/2 miles from ground zero for both shots.

5.2 SAMPLES

The indicators were mounted face down on the surface of 1/2 inch plywood and held in place with adhesive tape along the edges. They were covered with an .001 inch vinyl film to protect the indicators from solvents in the cream, and the cream was applied over the film. The film was folded over the edge of the plywood but otherwise was not adhered to the indicators or backing. An attempt was made to control the thickness of the cream by using spacers in the application. For the two thicker applications, an excess of material was applied and scraped off with a straight edge riding on 1/16 and 1/32 in. flat spacers. The thinner sample was applied without spacers and the thickness was less definite and less uniform.

The samples were prepared as late as possible on the day before the shot but even so, this was at least 12 hours before exposure. They dried out considerably in that time but no measure was made of the moisture content.

The reflectance of this material was measured, freshly prepared and after drying overnight the curve in Fig. 2.1 is the average. The average reflectance was about 37 percent in the visible and 32 percent in the near infra red region. The difference between them was about 1.5 percent throughout the range. In the visible and near infra red regions the transmittance is negligible.

The density of the cream is about 1.55 grams per cubic centimeter and as a thin film the loss in weight may be 2 to 5 percent in 24 hours. A density of 1.55 grams per cubic centimeter is equivalent to weights of 71, 36, and 18 ounces per sq. yd. for 1/16, 1/32, and 1/64 inch films.

5.3 DAMAGE TO THE CREAM

Below 5 langleys there was no visible effect on the cream. At ~~12~~ 10

to 13 langleys there was evidence of small bubbles but no other damage.

5.4 PROTECTIVE VALUE

The protective value of the cream as shown by the temperature indicators is given in Table 5.1. Here the protection is the combined effect of cream and the .001 in. vinyl film.

The cream provides considerable protection, the indicators covered with only a .001 in. vinyl sheet were badly charred or completely gone with indicated temperatures above 257°C. With various thicknesses of cream the temperature ranged from 205 to 48°C.

At first sight there is an apparent discrepancy between the two results at 5 and 13 langleys on Shot 8 with temperatures of 62°C at 5 and 48°C at 13 langleys. However, the thickness was greater for the latter, .05 in. compared to .04 in. The protection increases rapidly with thickness and apparently the effect was great enough to cause this difference in temperatures.

It is difficult to express the results in terms of skin burns. If the tentative figure of 141°C from fabric studies is taken here, then possibly 2+ burns would have occurred at 4 and 5 langleys with 1/64 in. of cream. However, this exposure should barely produce such burns with no protection and obviously from the temperatures shown there was considerable protection. On the other hand there would have been no burns at 10 or 15 langleys with 1/16 inch of cream and there would certainly have been severe burns on unprotected skin.

Possibly some additional idea of the protective value can be obtained from other data on unprotected indicators. At about 4 miles from ground zero, the calculated exposures were .6 and .8 langleys for Shots 6 and 8. Indicators with no protection and with a .001 in. vinyl sheet and a .003 in. transparent adhesive tape gave the temperatures shown in Table 5.2. In this case the transparent cover reduced the temperatures considerably, probably mainly by reflecting some of the radiation. The protective value of the films where used in connection with the face cream was likely less and accordingly a temperature just less than 74-92°C can be used for comparison with the results in Table 4.2. Comparisons of this kind are somewhat risky unless the mechanisms of heat transfer are understood and can give only approximate answers. With that uncertainty in mind, it seems that conditions will be just about the same behind just slightly more than 1/32 in. of face cream at 4 to 5 langleys as with no face cream at .6 to .8 langleys.

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TABLE 5.1

Protection Afforded by QM Face Cream

Thickness, in.		Temperature, °C			
		Shot 6		Shot 8	
Estimated, as Applied	Measured after Return to Lab.	4 lang.	10 lang.	5 lang.	13 lang.
0	0	>257[a]	>257[b]	>257[a]	>257[b]
1/64	.01	100 161		118 205	
1/32	.02	68 92		79 175	
1/16	.04	<48	48[c]	62	<48[d]

a Paper of indicators very badly charred.
b Indicators completely gone.
c Thickness .06 in.
d Thickness .05 in.

TABLE 5.2

Temperature of Exposed Indicators

	Temperature, °C	
	Shot 6	Shot 8
	.6 langley	.8 langley
No protection	74-92	74[a] -- 92[a]
Under .001 in. vinyl sheet	62-74	
Under transparent adhesive tape, .003 in. total thickness		48 -- 62

a. Although the range is the same, probably slightly higher temperature than the corresponding indicator of Shot 6.

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CHAPTER 6

PACKAGING

6.1 GENERAL

Three wood boxes were exposed, one each at 2910, 4110 and 5810 feet from ground zero for Shot 8. Temperatures inside were measured with the indicators described in Section 2.3.

6.2 SAMPLES AND EXPOSURE

The boxes were 26 in. x 26 in. x 26 in., roughly constructed of 3/4 inch thick pine boards. A 3/4 in. board was fastened in a vertical position across the box at the center.

Indicators were mounted on the center board, face down and held in place with adhesive tape at the edges. The indicators were about 5 inches from the bottom of the box on the side of the board facing ground zero. The boxes were placed flat on the ground with the front edges normal to the beam. They were not fastened down.

The results are summarized in Table 6.1. These results are difficult to understand. They appear to be in reverse order with the highest temperature at the greatest distance. However, this effect was noticed at the time, and the sample identification was carefully checked. There is little chance that the data as listed do not refer to the correct locations.

It seems likely that in this case there was obscuration by dust, possibly from the shockwave but also possibly from the popcorn-like bursting of soil particles under the action of thermal radiation[5] which presumably could happen at these ~~intensities~~ EXPOSURES since it occurs in the laboratory at 11 langleys. The boxes were on the ground, with the highest point only 2 feet above the surface and dust could very well have reduced these intensities without influencing the radiation on fabrics higher off the ground.

If this analysis is correct then the temperatures at 2910 and 4110 feet are too low by a considerable amount. The result at 5810 feet is also uncertain; it represents a minimum figure. Even if the temperatures at that distance without dust should be as low as 56 to 74°C, the corresponding temperatures at 4110 and 2910 feet would be considerably higher. The radiation intensities were roughly 2 and 4 times as great but it is difficult to estimate the difference in the resulting temperatures.

[redacted]

TABLE 6.1

Results of Packaging Test

Distance from Ground Zero, Ft.	Radiant Exposure langleys	Damage to Box: Thermal	Damage to Box: Blast	Temperature Inside Box, °C
2910	40	Side facing the explosion charred deeply, 1/16 to 1/8 in. deep	One board blown off bottom of box. Box moved 65 ft.	<48
4110	20	Side of box facing explosion charred	One board blown off box. Box moved 30 ft.	48
5810	10	Side of box facing the explosion slightly scorched	Box turned over	56-74

[redacted]

[redacted]

[redacted]

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